CLAIMS

1. An ATM transmission system, adapted for the transmission of IP data and including a core network of ATM switches, said ATM transmission system being adapted to handle inter-subnet communications, characterised in that said core network includes access IP/ATM nodes (AINs) and core IP/ATM nodes (CINs) for handling said inter-subnet communications, in that each AIN is attached to an ATM switch of the core network through an ATM User-Network Interface (UNI) and is adapted to perform IP data flow classification and labelling for facilitating mapping of IP data flows to ATM VCs, and to communicate with IP/ATM hosts and routers, in that each CIN is attached to an ATM switch of the core network through an ATM UNI and is adapted to perform routing and labelling, in that said AINs and CINs are interconnected through Virtual Path Connections (VCPs), and in that permanent VCPs are set-up between adjacent CINs.

2. An ATM transmission system, as claimed in claim 1, characterised in that said AINs are adapted to communicate with non-ATM hosts.

3. An ATM transmission system, as claimed in claim 2, characterised in that said AINs are adapted to communicate with non-ATM hosts using Ethernet.

4. An ATM transmission system, as claimed in any preceding claim, characterised in that said inter-subnet communications are effected on a hop-by-hop basis, and in that said ATM transmission system is adapted to map each IP data flow into an ATM Virtual Circuit (VC) for each hop, between nodes, on the communication path towards a destination subset.

5. An ATM transmission system, as claimed in claim 4, characterised in that the ATM VC for each hop between nodes is a VCI selected from a VPC connecting the two nodes.

6. ATM transmission system, as claimed in any preceding claim, characterised in that each AIN is adapted, on receipt of an IP data packet from an IP/ATM host for transmission to a destination subnet, to reassemble the IP data packet, decrement a TTL

(Time To Live) timer, discarding the IP data packet if the timer reaches zero, compute the IP data packet header checksum, and check whether the destination subnet is supported by the AIN and, if so, send the IP data packet on that subnet.

7. An ATM transmission system, as claimed in claim 6, characterised in that each AIN includes, and is adapted to maintain, a labelling table and a standard IP forwarding table, the entries of which are completed by an IP routing protocol.

8. An ATM transmission system, as claimed in claim 7, characterised in that each entry in said labelling table includes a subnet address, the outgoing VC (VPI/VCI) to reach the subnet, and a timer for the VC, and in that the timer is adapted to be started whenever IP packets are sent on the VC.

9. An ATM transmission system, as claimed in any of claims 6 to 8, characterised in that, in the event that the destination subnet is not supported by the AIN, said AIN is adapted to identify an existing ATM VC towards said destination subset and to send the IP data packet on an identified existing ATM VC.

10. An ATM transmission system, as claimed in claim 9, characterised in that, in the event that an existing ATM VC is not identified, said AIN is adapted to identify the next hop on the path to the destination subnet, by consulting its forwarding table, and to chose, and send the IP packet on, a free VCI from the VPC to the next hop, and in that said AIN is adapted to update its labelling table by making an entry containing the destination subnet address and the chosen VC, and to restart the entry's timer, said timer having a lifetime value for the VC.

11. An ATM transmission system, as claimed in claim 10, characterised in that said next hop on the path to the destination subnet is a CIN.

12. An ATM transmission system, as claimed in any one of the preceding claims, characterised in that each AIN is adapted to listen to the VPCs to which it is set up, to reassemble the cells coming from the core network into IP packets, to perform computations on TTL and header checksum, and to route valid packets towards ATM

hosts/routers attached to an access network.

13. An ATM transmission system, as claimed in any one of the preceding claims, characterised in that each CIN is adapted to:

- listen to the VPCs to which it is set up;
- retrieve an IP packet from a cell received on a VCI of one of said VPCs;
- decrement a TTL and compute the IP packet header checksum;
- consult its labelling table to determine if there is an outgoing VC already in existence to a destination subnet to which the IP packet is to be sent; and
- if an existing outgoing VC is identified, send the IP packet on that VC and restart the VC's timer.

14. An ATM transmission system, as claimed in claim 13, characterised in that, in the event that an existing outgoing VC is not identified, said CIN is adapted to identify the next hop on the path towards the destination subnet by consulting its IP forwarding table, and to chose a free VCI from the VPC to the next hop, in that said CIN is adapted to update its labelling table by making an entry containing the destination subnet address, the incoming VC, the outgoing VC and the free VCI chosen from the VPC to the next hop, and in that said CIN is adapted to set the VC timer for the newly created entry in said labelling table, send the IP packet on the outgoing VC and cross-connect the VC incoming to, and the VC outgoing from, its ATM switch, all cells thereafter received on said incoming VC being forwarded to said outgoing VC within said ATM switch.

15. An ATM transmission system, as claimed in claim 14, characterised in that said CIN is adapted to control said cross-connection using Switchlets, an Ariel interface being provided between said ATM switch and said CIN for cross-connecting said incoming and outgoing VCs of said ATM switch.

16. An ATM transmission system, as claimed in claim 15, characterised in that said cross-connected VCs are the VCIs of the incoming and outgoing Virtual Path (VP) links between said CIN's ATM switch and its two neighbouring ATM switches, one on an input side of, and the other on an output side of, said CIN's ATM switch.

17. An ATM transmission system, as claimed in any of claims 14 to 16, characterised in that said CIN is adapted to periodically monitor the cross-connected VCs in order to disconnect any VC found to be idle.

18. An ATM transmission system, as claimed in claim 17, characterised in that an Ariel interface is provided between said CIN and its ATM switch, and in that said CIN is adapted to use said Ariel interface to periodically monitor the cross connected VCs.

19. An ATM transmission system, as claimed in claim 17, or claim 18, characterised in that, in the event that an incoming VC is found to be inactive, said CIN is adapted to purge the corresponding outgoing VC from its labelling table, the corresponding incoming VC being cross-connected back to the CIN via a VP link on the CIN/ATM switch interface, and in that said CIN is adapted to re-enter the purged outgoing VC into its labelling table as a free VC.

20. An ATM transmission system, as claimed in any of claims 13 to 19, characterised in that each entry in a CINs labelling table contains:

- a list of all incoming, merged, VCs;
- the outgoing VC towards a destination subnet, said outgoing VC being used by the CIN during the merging of new incoming VCs and is established when a new entry is created in the labelling table;
- the destination subnet address; and
- VC timers, one for each incoming VC.

21. An ATM transmission system, as claimed in claim 20, characterised in that each CIN is adapted to merge a new incoming VC with an outgoing VC, each CIN being adapted to listen to the VPCs to which it is set up and to:

- retrieve an IP packet received on a VCI of one of said VPCs
- decrement the TTL and compute the IP packet header checksum;
- consult its labelling table to determine if there is an outgoing VC already in existence to the destination subnet to which the retrieved IP packet is to be sent;
- if an existing outgoing VC is identified, send the IP packet on that VC to the destination subnet, the CIN merging the incoming VC to the outgoing VC to the subnet; and
- in the event that the incoming VC is not included in the list of incoming VCs in its labelling table, add it to said labelling table.

22. An ATM transmission system, as claimed in claim 21, characterised in that, in the event that an existing outgoing VC is not identified, each CIN is adapted to find the next hop on the path towards the destination subnet by consulting its IP forwarding table and to chose a free VCI from the VPC to the next hop, in that said CIN is adapted to update its labelling table by making an entry containing the destination subnet address, the incoming VC (first in the VC list), the outgoing VC and the free VCI chosen from the VPC to the next hop, and in that said CIN is adapted to send the IP packet on the outgoing VC, to merge the incoming VC to the outgoing VCs using a CIN/ATM switch interface and to start a timer for the incoming VC, all cells thereafter received on said incoming VC being forwarded to the outgoing VC within said ATM switch.

23. An ATM transmission system, as claimed in any of claims 14 to 16, characterised in that each CIN is adapted to periodically monitor the cross-connected/merged VCs in order to disconnect any VC found to be idle.

24. An ATM transmission system, as claimed in claim 23, characterised in that, in the event that an incoming VC is found to be inactive, said CIN is adapted to purge the corresponding outgoing VC from its labelling table, the incoming VC being cross-connected back to the CIN via a VP link on the CIN/ATM switch interface, and in that, in the event that the VC list becomes empty, said CIN is adapted to return the purged outgoing VC to its labelling table and to delete the entry for the subnet from the labelling table.

25. An ATM transmission system as claimed in any of claims 13 to 24, characterised in that, in the event of rerouting of an IP packet, the CIN is adapted to assign new VCs to the affected subnet addresses in its labelling table, based on new routes for the IP packet, the old VCs, after being timed out, being re-entered in the labelling table as free VCs.

26. An ATM transmission system, as claimed in any preceding claim, characterised in that said system is adapted to provide Quality of Service (QoS) support by setting up CBR VPCs in parallel to UBR VPCs; in that each AIN is adapted to assign service classes to data flows and give an indication of the data rate assigned to each flow using the type of service field in the IP packet header; and in that each CIN is adapted, on receipt of an IP packet on a CBR VC, to first find a free outgoing CBR VC towards the destination subnet, allocate a required data rate based on the type of service value, send the IP packet on the free outgoing CBR VC, and finally, cross-connect the incoming and outgoing VCs at its ATM switch.

27. A method of transmitting IP data over an ATM transmission system having a core network including a number of ATM switches, said method being adapted to handle inter-subnet communications, on a hop-by-hop basis, and characterised by the steps of:

- said inter-subnet communications being effected using access IP/ATM nodes (AINs) and core IP/ATM nodes (CINs) of said core network;

- each AIN communicating with an IP/ATM host and performing IP data flow classification and labelling;

- an AIN, on receipt of an IP data packet from an IP/ATM host, for transmission to a destination subnet, reassembling the IP data packet;

- decrementing a TTL (Time To Live) timer by 1 and discarding the IP data packet if the timer reaches zero;

- computing the IP data packet header checksum; and

- checking whether the destination subnet is supported by the AIN and, if so, sending the IP data packet on that subnet.

28. A method, as claimed in claim 27, characterised by said AIN maintaining a labelling table and a standard IP forwarding table filled by an IP routing protocol.

29. A method, as claimed in claim 28, characterised by each entry in said labelling table including:

- a subnet address;

- the outgoing VC (VPI/VCI) to reach the subnet; and

- a timer for the VC, the timer being started whenever IP packets are sent on the VC.

30. A method, as claimed in claim 29, characterised by the steps of:

- in the event that the destination subnet is not supported by the AIN, consulting the labelling table of said AIN to determine if there is an ATM VC already in existence towards the destination subset to which the packet is to be sent; and

- if an existing ATM VC is identified, said AIN:

- hashes on the subnet address;
- sends the packet on the identified VC; and
- restarts the timer.

31. A method, as claimed in claim 30, characterised by the steps of:

- consulting the forwarding table of said AIN, in the event that an existing ATM VC is not identified, to find the next hop on the path to the destination subnet;
- finding a free VCI from the VPC to the next hop;
- sending the IP packet on a chosen VCI;
- creating, in the labelling table of said AIN, an entry containing the destination subnet address and the VC; and
- restarting the entry's timer, said timer having a lifetime value for the VC.

32. A method, as claimed in claim 31, characterised by said next hop on the path to the destination subnet being a CIN.

33. A method, as claimed in any of claims 30 to 32, characterised by the step of using VC multiplexing (null encapsulation) of IETF RFC 1483 to encapsulate IP packets sent on said ATM VCs

34. A method as claimed in any of claims 29 to 33, characterised by the steps of:

- purging a VC entry from the labelling table of an AIN, in the event that a corresponding VC timer times out, the purged VC being cached for a period of time before becoming available for use;

- forcing all downstream VCs, in the path to the destination subnet, to be timed out; and

- if rerouting occurs to new routes, the affected subnet addresses found in the labelling table are assigned new VCs, based on the new routes, the old VCs becoming free after being timed out.

35. A method, as claimed in any of claims 27 to 34, characterised by the steps of:

- listening to the VPCs set up to an AIN;

- reassembling the cells coming from the core network into IP packets;

- performing computations on TTL and header checksum; and

- routing valid packets towards ATM hosts/routers attached to an access network.

36. A method, as claimed in any of claims 27 to 35, characterised by the steps of:

- listening to the VPCs set up to a CIN;

- reassembling a cell, received by the CIN on a VCI of one of said VPCs, to retrieve an IP packet;

- decrementing the TTL and computing the IP packet header checksum;

- consulting a labelling table of the CIN to determine if there is an outgoing VC already in existence to a destination subnet to which the IP packet is to be sent; and

- if an existing outgoing VC is identified, the CIN sends the IP packet on that VC and restarts its timer.

37. A method, as claimed in claim 36, characterised by the steps of:

- consulting an IP forwarding table of the CIN, in the event that an existing outgoing VC is not identified, to find the next hop on the path towards the destination subnet;

- finding a free VCI from the VPC to the next hop;

- creating, in the labelling table of said CIN, an entry containing the:

  - destination subnet address;

  - the incoming VC;

  - the outgoing VC, the free VCI chosen from the VPC to the next hop;

- setting the VC timer for the newly created entry in the CIN's labelling table;

- sending the IP packet on the outgoing VC; and

- cross-connecting the incoming and outgoing VCs of the CIN's ATM switch, all cells thereafter received on said incoming VC being forwarded to said outgoing VC within said ATM switch.

38. A method, as claimed in claim 37, characterised by the step of cross-connecting said incoming and outgoing VCs of said ATM switch using an Ariel interface between said switch and said CIN.

39. A method, as claimed in claim 38, characterised by said cross-connected VCs being the VCIs of the incoming and outgoing Virtual Path (VP) links between the CIN's ATM switch and its two neighbouring ATM switches, one on an input side of, and the other on an output side of, said CIN's ATM switch.

40. A method, as claimed in any of claims 37 to 39, characterised by said CIN periodically monitoring the cross connected VCs in order to disconnect any VC found to be idle.

41. A method, as claimed in claim 40, characterised by using an Ariel interface between said CIN and its ATM switch to periodically monitoring the cross connected VCs.

42. A method, as claimed in claim 40, or claim 41, characterised by the steps of:

- in the event that an incoming VC is found to be inactive, the corresponding outgoing VC is purged from the CINs labelling table;
- the outgoing VC is put back into the labelling table as a free VC; and
- the incoming VC is cross-connected back to the CIN via a VP link on the CIN/ATM switch interface.

43. A method, as claimed in any of claims 36 to 42, characterised by each entry in a CINs labelling table containing:

- a list of all incoming, merged, VCs;
- the outgoing VC towards a destination subnet, said outgoing VC being used by the CIN during the merging of new incoming VCs and is established when a new entry is created in the labelling table;
- the destination subnet address; and
- VC timers, one for each incoming VC.

44. A method, as claimed in claim 43, characterised by said merging of a new incoming VC with the outgoing VC including the steps of:

- each CIN listening to the VPCs set up to it, an IP packet received on a VCI of one of the VPCs being retrieved by the CIN;

- decrementing the TTL and computing the IP packet header checksum;

- consulting the CIN's labelling table to determine if there is an outgoing VC already in existence to the destination subnet to which the retrieved IP packet is to be sent;

- if an existing outgoing VC is identified, the CIN sends the IP packet on that VC to the destination subnet, the CIN merging the incoming VC to the outgoing VC to the subnet; and

- in the event that the incoming VC is not included in the list of incoming VCs in the CIN's labelling table, it is added to the table by the CIN.

45. A method, as claimed in claim 44, characterised by the steps of:

- consulting an IP forwarding table of the CIN, in the event that an existing outgoing VC is not identified, to find the next hop on the path towards the destination subnet;

- finding a free VCI from the VPC to the next hop;

- creating, in the labelling table of said CIN, an entry containing the:

  - destination subnet address;

  - incoming VC (first in the VC list);

  - outgoing VC, the free VCI chosen from the VPC to the next hop;

- sending the IP packet on the outgoing VC; and

- merging the incoming VC to the outgoing VCs using the CIN/ATM switch interface and starting a timer for the incoming VC, all cells thereafter received on said incoming VC being forwarded to the outgoing VC within said ATM switch.

46. A method, as claimed in any of claims 37 to 45, characterised by said CIN periodically monitoring the cross connected/merged VCs using the CIN/ATM switch interface in order to disconnect any VC found to be idle.

47. A method, as claimed in claim 45, characterised by the steps of:

- in the event that an incoming VC is found to be inactive, the corresponding outgoing VC is purged from the CINs labelling table;

- the incoming VC is cross-connected back to the CIN via a VP link on the CIN/ATM switch interface; and

- if the VC list becomes empty, the outgoing VC is returned as a free VC and the entry for the subnet is deleted from the CIN's labelling table.

48. A method as claimed in any of claims 36 to 47, characterised by, in the event of rerouting of an IP packet, the affected subnet addresses in the CIN's labelling table are assigned new VCs based on new routes for the packet, and the old VCs are put back as free VCs, after being timed out.

49. A method, as claimed in any of claims 27 to 48, characterised by providing Quality of Service (QoS) support by setting up CBR VPCs in parallel to UBR VPCs; by each AIN assigning service classes to data flows and giving an indication of the data rate assigned to each flow using the type of service field in the IP packet header; and by a CIN, on receipt of an IP packet on a CBR VC:

- first finding a free outgoing CBR VC towrads the destination subnet;

- allocating the required data rate based on the type of service value;

- sending the IP packet on the free outgoing CBR VC; and

- finally, cross-connecting the incoming and outgoing VCs at the CIN's ATM switch.

50. An IP/ATM network including an ATM transmission system as claimed in any of claims 1 to 26, or using a method as claimed in any of claims 27 to 49.